

What Reliability Engineers Should Know about Space Radiation Effects

Abstract

Space radiation in space systems present unique failure modes and considerations for reliability engineers. Radiation effects is not a one size fits all field. Threat conditions that must be addressed for a given mission depend on the mission orbital profile, the technologies of parts used in critical functions and on application considerations, such as supply voltages, temperature, duty cycle, and redundancy. In general, the threats that must be addressed are of two types—the cumulative degradation mechanisms of total ionizing dose (TID) and displacement damage (DD), and the prompt responses of components to ionizing particles (protons and heavy ions) falling under the heading of single-event effects. Generally degradation mechanisms behave like wear-out mechanisms on any active components in a system:

Total Ionizing Dose (TID) and Displacement Damage:

- TID affects all active devices over time. Devices can fail either because of parametric shifts that prevent the device from fulfilling its application or due to device failures where the device stops functioning altogether. Since this failure mode varies from part to part and lot to lot, lot qualification testing with sufficient statistics is vital. Displacement damage failures are caused by the displacement of semiconductor atoms from their lattice positions. As with TID, failures can be either parametric or catastrophic, although parametric degradation is more common for displacement damage. Lot testing is critical not just to assure proper device functionality throughout the mission. It can also suggest remediation strategies when a device fails. This paper will look at these effects on a variety of devices in a variety of applications. This paper will look at these effects on a variety of devices in a variety of applications.
- On the NEAR mission a functional failure was traced to a PIN diode failure caused by TID induced high leakage currents. NEAR was able to recover from the failure by reversing the current of a nearby Thermal Electric Cooler (turning the TEC into a heater). The elevated temperature caused the PIN diode to anneal and the device to recover. It was by lot qualification testing that NEAR knew the diode would recover when annealed. This paper will look at these effects on a variety of devices in a variety of applications.

Single Event Effects (SEE):

- In contrast to TID and displacement damage, Single Event Effects (SEE) resemble random failures. SEE modes can range from changes in device logic (single-event upset, or SEU), temporary disturbances (single-event transient) to catastrophic effects such as the destructive SEE modes, single-event latchup (SEL), single-event gate rupture (SEGR) and single-event burnout (SEB)
- The consequences of nondestructive SEE modes such as SEU and SET depend critically on their application—and may range from trivial nuisance errors to

catastrophic loss of mission. It is critical not just to ensure that potentially susceptible devices are well characterized for their susceptibility, but also to work with design engineers to understand the implications of each error mode.

- For destructive SEE, the predominant risk mitigation strategy is to avoid susceptible parts, or if that is not possible, to avoid conditions under which the part may be susceptible. Destructive SEE mechanisms are often not well understood, and testing is slow and expensive, making rate prediction very challenging.
- Because the consequences of radiation failure and degradation modes depend so critically on the application as well as the component technology, it is essential that radiation, component, design and system engineers work together—preferably starting early in the program to ensure critical applications are addressed in time to optimize the probability of mission success.

Subject Topic: Applications in Aerospace

Author: R.C. DiBari

Summary

Space Radiation in space systems presents unique failure modes and considerations for reliability engineers. Radiation effects is not a one size fits all field. Knowing how radiation can affect a system can improve the overall reliability of space systems. This paper will look at these effects on a variety of devices in a variety of applications.

This paper will look at the primary failure modes caused by Total Ionizing Dose (TID), Displacement Damage and Single Event Effects (SEE).

Biography

Becky DiBari has a Masters degree in Physics from Rensselaer Polytechnic Institute, and has done research in material physics and nuclear physics. She spent 8 years doing radiation effects analysis for Honeywell International and in the Radiation Effects and Analysis group at NASA GSFC. She has worked in the Reliability and Risk Analysis group at NASA GSFC for the past 6 years.